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Assessment of the impact of the different point sources of pollutants on the river water quality and the evaluation of bioaccumulation of heavy metals into the fish ecosystem thereof

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Abstract: The present study focuses on the evaluation of the river (Ganga) water quality by estimating various quality indicators (also termed the physicochemical parameters) such as pH, temperature, dissolved oxygen (DO), electrical conductivity (EC), chlorides, sulfates, phosphates, hardness, chemical oxygen demand (COD), biochemical oxygen demand (BOD5). Rise in the concentration of the pollution signifies an upsurge in a load of pollution due to the different sources namely, sewage arising from domestic sources, effluents arising from industrial discharge, and effluents arising due to various anthropogenic activities. For the purpose of the comparative evaluation of the river water quality, the water samples were collected from the three different banks of the Ganga River for a well-organized interpretation.Obtained results indicate thatthe discharge of the various effluents has a grave impact on the water quality of the river. Industrial effluents mixing with the river water were noted to have the most deleterious impact on the deterioration of the water quality parameter. The extended aim of the study was to collect the fish samples from the three above-mentioned sampling points and thereby detect the presence of the heavy metal concentration (determined through atomic absorption spectroscopy or AAS). Obtained results also indicates that the fish specimen collected from the sampling point where the industrial effluents are mixing have the highest levels of heavy metals in the tissues of the selected fish sample. Accordingly, the study indicated a novel approach toward the characterization of the river water and thereby indicating the impact of bioaccumulation of heavy metals into the fishtissues which indicates the novelty of this work. The authors strongly believe that this work will be beneficial to various stakeholders and will be definitely helpful to various competent national and international authorities for decision-making and strategies formulation.

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Introduction

Water is an important resource to promote overall sustainability (Roy and Ray, 2019). Nowadays water pollution has became a terrible problem for most of the rivers of India (Biswas and Saha, 2021; Chakraborty et al., 2019). The Ganga being the longest rivers in the Indian subcontinent plays an important role in socio-economic development and also considered as major source of drinking water and irrigation (Parua, 2010). Furthermore, the Ganga River is also used for various industrial purposes (Kumar, 2020). The main river stream originates in the glacier of Gangotri at 30°55' N, 79°7' E as the name of 'Bhagirathi'. The catchment area of the Ganga lies between east longitudes 73°30' to 89°0' and north latitudes 22°30' to 31°30' which falls in four countries but major portion,nearly 862769 Km2 lying in India and its almost 26.2% of the total geographical area of this country.

fluents arising from the industry are finally dumped into the river (Ghoshal et al., 2022).

The quality of the potable water banks on various water sources like wells, rivers, ponds, etc. (Chowdhury et al., 2016; Mallick et al., 2016; Mallick, 2017) and can also be degraded by the action of several point sources like contaminants, pollutants, chemical compounds, toxic compounds, herbicides, pesticides, etc. to name a few (Madhav et al., 2020; Saha et al., 2017). Various effluents which are directly flushed (containing various toxic components) out into the Ganga have been reported to have various deleterious impacts on the water of the Ganges (Roy et al., 2021). Such mixing of the contaminants has also been reported to impact the different components of the ecosystem (Bhattacharya et al., 2016). The bioaccumulation caused thereby has also been reported to have an impact on human health (Kour et al., 2021).

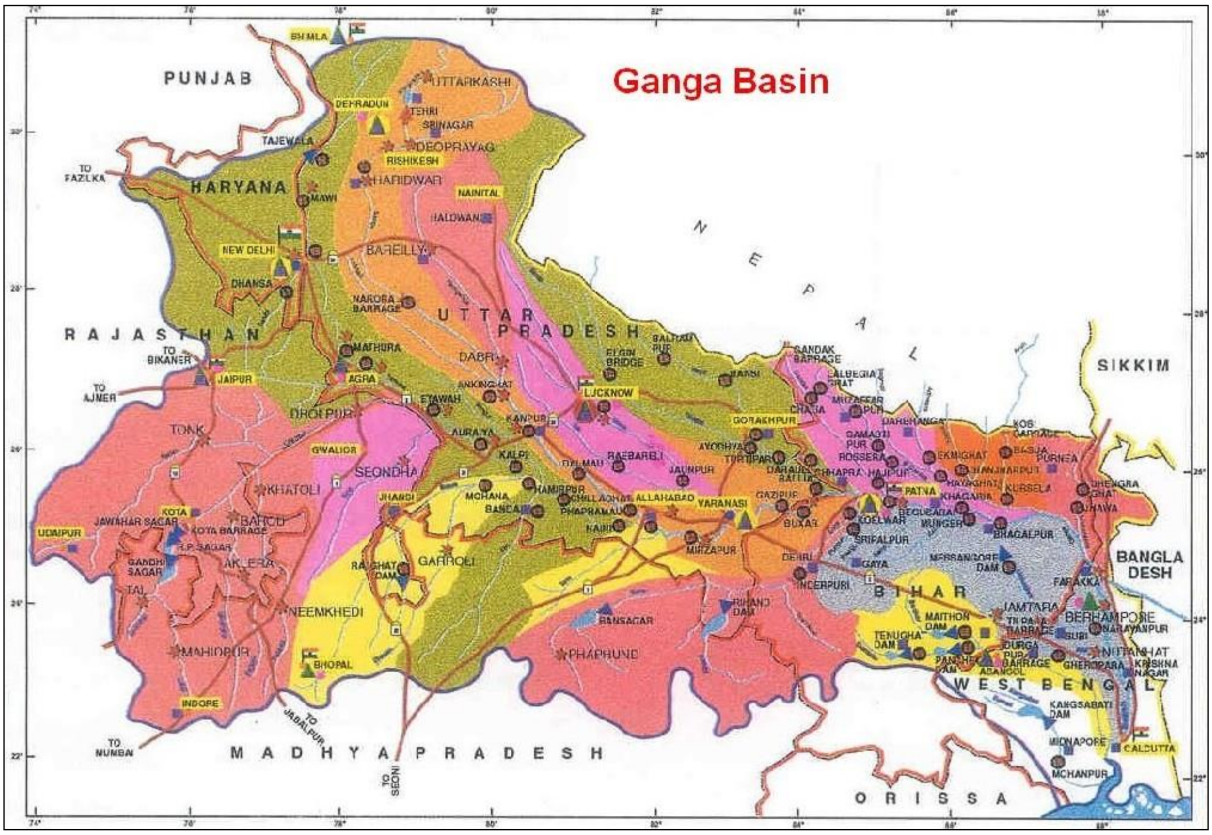

Figure 1. Map of the Ganga basin (Source:www.wrmin.nic.in).

However, due to the release of various contaminants and pollutants from different sources, the river water is getting contaminated day by day (Roy et al., 2021). In the past few decades, the population has increased in multifolds, which in turn has created a gamut of environmental concerns (Roy and Ray, 2020). A few of the major causes behind such changes are urbanization, deforestation, rapid industrialization, etc (Roy and Ray, 2021; Bhattacharya, 2015). Major impact of such activities has deeply affected the quality of the river water since most of the ef-

Materials and Methods

Study area and collection of samples

The water sample was collected from three sites on the Ganga river. For better results, surface water was avoided sample water was collected from 2 feet depth. The three different sites were sewage arising from domestic sources (indicated as site A), effluents arising from industrial discharge (indicated as site B) and effluents arising due to various anthropogenic activities (indicated as site C). The

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entire water sample was collected in sterile autoclaved glass containers in the month of February 2022 and therefore was processed within 5 hours and was stirred at -20°C until further use. The fish samples were also collected from the three above-mentioned sites. The average weight of the fish was around 100-120 grams. Adult fishes were chosen to have better insight into the impact of heavy metals in bioaccumulation. The fish specimens were stirred inside the ice pack and were immediately sent to the laboratory for analysis.

Methodology

Accordingly, an imperative research scope was identified for the evaluation of the impact of the various types of effluents mixing in the water quality parameter of the river Ganga. Thus, aim of the present study was fragmented into two major segments. Initial aim of the study was focused on the determination of the water quality parameter from different points of the river Ganga, where different forms of pollutants were mixing. Whereas extended aim was to determine the amount of bioaccumulated heavy metals within the fish population (conclusion arrived on the sampling of the representative fishes from the three-point sources) which in turn will give a clear indication regarding the bioaccumulation of the heavy metals. The scheme of study adopted in the present study will be beneficial to the various stakeholders and is believed to uphold the overall environmental sustainability. The entire schematic representation has been indicated in figure 2. As per the author's best knowledge, such studies have not been conducted elsewhere which in turn indi-cates the novelty of the present study.

Various physicochemical analysis of river water collected from three points were conducted in this study. The fixed residue and the total dissolved solids were determined by following the evaporation method. The sodium thiosulphate methods were adopted to determine the dissolved oxygen and biochemical oxygen demand of the collected water samples. The COD of the water samples was measured by adopting standard literature reports (Cazaudehore, 2019).

Analysis of fish specimen was conducted by dissecting the internal organs of the fishes. Before that, the scales of the fishes were removed. The various dissected fish tissues (muscle, liver, and gills) were dried in a hot air oven for 8 hours at 105±5°C. The dried tissues were thereby ground with the help of a mortar and pestle. One gram of the ground tissues was thereby collected and were digested with 4 ml of perchloric acid and 8 ml of nitric acid. The resulting mixture was transferred to the sealed tubes and was placed in a boiling water bath for dissolving the tissues for an hour. After one hour, the solution was cooled and was stored in sealed containers after filtration. The entire protocol was adopted from a previous literature report (Mensoor, 2018). The determination of the heavy metals was carried out by an atomic absorption spectrophotometer (Perkin Elmer model 5000, PerkinElmer Corp, Waltham, MA, USA) following the standard protocol (Zschunke, 2000). All the experiments were carried out in triplicates to estimate the associated errors.

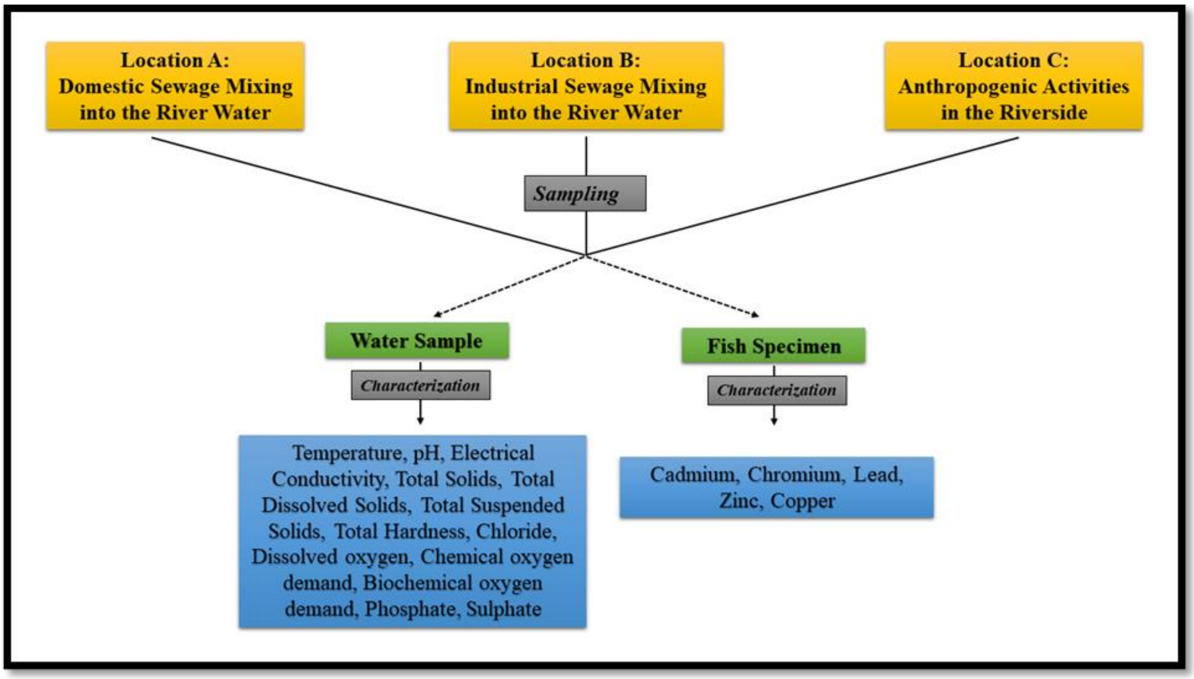

Figure 2. Schematic presentation of the entire experimental plan.

All the chemicals required for the experimental purpose were procured from Nice® Chemical (Kerala India).

Results and Discussions:

Water samples collected from the three different point sources were characterized for their physicochemical properties in terms of Temperature, pH, electrical conductivity (EC), total solid (TS), total dissolved solids (TDS), total soluble solids (TSS), total hardness (TH), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), chloride, phosphate (PO4), and Sulfate (SO4). The obtained results have been indicated in table 1.

It was observed from the obtained results that the temperature of the water was found in the range between 27.120 ± 0.012 to 28.128 ± 0.013°C for the different water samples evaluated in this study. The highest temperature was noted for the location site B where industrial effluents are mixing with the river water. Thus, it was inferred that the mixing of the industrial effluents has the maximum impact on the elevation of the temperature of the water which in turn has a grave impact on the aquatic ecosystem. A similar drift was noted with the change in pH due to the mixing of various kinds of wastewater. The highest disturbance was noted for location B where industrial effluents are mixing with the river water. It was noted that upon such intermixing, the river water turns into the slightly acidic range which in turn results in the river water acidification. Thus the industrial effluents haveenough potential for the acidification of the river water which in turn might result in the disturbance of the aquatic ecosystem. The water sampled from the other two locations (locations A and C) were found near the neutral pH which indicates that these effluents havea minimal impact on the acidification potential of river water and are accordingly noted to be relatively safer.The electrical conductivity of the water samples collected from three different locations was evaluated to determine the presence of free ions in terms of electrical conductivity. The presence of free ions is an indicator of water pollution (Madhav et al., 2020). The data presented in table 1 indicated that the highest electrical conductivity was noted for location B (825 ± 13.221 µS/cm-1) where the industrial effluents were mixed with the river water. Accordingly, it would be advisable that the wastewater generated from the different industries should be properly treated prior to disposalin the river.If such precautions are not adopted, these effluents can harm the aquatic ecosystem. The different types of solid particles (in terms of TS, TDS, and TSS), TH,and chloride present in the water samples collected from the three different studied locations were evaluated to corroborate the findings obtained from the EC and pH.The results indicated in the Table 1 gleaned that the presence of the highest amounts of the solid particles (TS, TDS, and TSS) was noted for the water collected from location B wherethe industrial effluents were mixing. A similar impact was noted with the total hardness and chloride ions. The obtained results match with the result obtained from the electrical conductivity. The presence of the higher amounts of solid particles, total hardness, and chloride ions in turn increased the electrical conductivity of the river water collected from

Table 1. Summary of the physicochemical properties of waters collected from different locations.

Sl No.	Parameters	Site A (Domestic sewage)	Site B (Industrial sewage)	Site C (Anthropogenic activity)	Standard as per WHO (1993)
1	Temperature (°C)	27.454 ± 0.012	28.128 ± 0.013	27.120±0.012	20-30
2	pH	7.242 ± 0.002	6.787 ± 0.003	7.328 ± 0.002	6.5 – 8.5
3	EC (µS/cm^{-1})	598 ± 11.232	825 ± 13.221	545 ± 10.909	1000
4	TS (mg/l)	1287 ± 118.989	1656 ± 120.050	1198 ± 121.982	NA
5	TDS (mg/l)	878 ± 112.332	1232 ± 154.565	902 ± 121.992	1000
6	TSS (mg/l)	434 ± 29.898	687 ± 32.002	589 ± 28.006	10
7	TH (mg/l)	180 ± 12.885	386 ± 19.998	196.817 ± 15.117	500
8	Chloride(mg/l)	208 ± 18.906	427 ± 23.772	296 ± 21.343	250
9	DO (mg/l)	5.787 ± 0.046	5.106 ± 0.032	4.928 ± 0.022	6
10	COD (mg/l)	267 ± 23.727	340 ± 12.210	254 ± 9.998	250
11	BOD_5 (mg/l)	31.454 ± 1.213	39.878 ± 2.224	34.402 ± 1.118	30
12	PO_4 (mg/l)	4.565 ± 0.909	5.672 ± 1.008	4.289 ± 1.232	0.1
13	SO_4 (mg/l)	23.667 ± 1.232	29. 232 ± 0.962	22.820 ± 0.897	NA

NA: Not Available

location B. The higher presence of such particles can choke into the gills of the fishes present in the river water which in turn might cause their death (Mallik et al., 2021). Such particles have also been reported to be deposited on aquatic plants and thereby clogging their stomatal openings (Kameswaran et al., 2019). The presence of the different types of solid particles, total hardness, and chloride ions was found to be much lower in the case of the water samples collected from the other two locations (locations A, and C) which in turn indicates that the industrial effluents have a severely detrimental impact on the river water.The dissolved oxygen was found within the range of 4.928 ± 0.022 and 5.787 ± 0.046 mg/ml. The minimum DO content was noted for the water sample collected from location C. In location C, maximum anthropogenic activities take place. Various anthropogenic activities release different alkaline compounds which decrease the dissolved content of the water. The lowered dissolved oxygen content has been reported to have a detrimental impact on the aquatic flora and fauna (Kumar et al. 2012). The BOD and COD were determined for the water specimens collected from the three different locations indicated in the studies to determine the amount of organic pollution present in an aquatic ecosystem. The data presented in Table 1 indicates that the highest BOD and COD were determined for location B where the industrial effluents are mixing with the river water. The obtained results were found to be in line with the data obtained from the previous experiments conducted in this study. Finally, the amount of sulfate and phosphate levels were determined for the water samples from the three locations evaluated in this study. It was noted that the highest amount of sulfate and phosphate were observed in the water sample where the industrial effluents are mixed (Location B). The result of mixing such industrial effluents will increase the eutrophication and acidification potential of the water quality which will, in turn, result in the deterioration of the flora and fauna of the river water.

Table 2. Concentration of the different heavy metals collected from the gills of the fishes from the various locations evaluated in this study.

Heavy metals (μg/g)	Site A (Domestic sewage)	Site B (Industrial sewage)	Site C (Anthropogenic activity)
Tissue collected from the gills of the fishes			
Cadmium	2.124 ± 0.121	2.982 ± 0.101	2.288 ± 0.113
Chromium	1.809 ± 0.109	2.121 ± 0.112	1.982 ± 0.119
Lead	1.022 ± 0.088	1.686 ± 0.082	1.368 ± 0.152
Zinc	0.962 ± 0.063	1.114 ± 0.084	0.986 ± 0.101
Copper	1.221 ± 0.116	1.684 ± 0.191	1.105 ± 0.092
Tissue collected from the liver of the fishes			
Cadmium	2.443 ± 0.113	2.876 ± 0.111	1.808 ± 0.118
Chromium	1.870 ± 0.096	2.205 ± 0.136	1.884 ± 0.101
Lead	1.118 ± 0.081	1.672 ± 0.074	1.208 ± 0.102
Zinc	1.612 ± 0.086	1.114 ± 0.088	0.894 ± 0.091
Copper	0.456 ± 0.056	0.694 ± 0.058	0.504 ± 0.042

All the obtained results indicated that the mixing of the industrial effluents into the river water has a grave impact on the water quality. Accordingly, we arrived at the conclusion that the industrial effluents should be treated properly prior to their disposal in the river water to prevent the deterioration of the water quality.

The extended aim of the study was to assess the impact of the various effluents entering the river water at three different locations (A, B, C). The assessment was done by determining the concentration of the heavy metals within the liver of the fishes captured from those locations. The analysis was carried out by sacrificing the collected fish, digesting their liver, and thereby using atomic absorption spectroscopy to determine the levels of heavy metals like cadmium, chromium, lead, zinc, and copper. The tissues of the fishes were collected from the gills and the liver for the purpose of comparative evaluation. The concentration of the heavy metals was determined in the gills since fishes respire through the gills and accordingly, there are fair chances that the heavy metals will be deposited into their gills (Fiedler et al., 2020). Apart from that, the concentration of heavy metals was also evaluated from the liver tissues of the collected fishes from the three different locations. The tissue from the liver was chosen since the liver has been reported to be the hub of

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metabolism (Lu et al., 2016). All the obtained results have been reported in Table 2.

The results showcased in Table 2 indicate that a significant chunk of the heavy metal load was found in the gill and liver of the fishes which were collected from the river water collected from the three different locations. The obtained results were indeed thought-provoking.The highest dosage of bioaccumulation of the heavy metals within the fishes was noticed which were collected from location B where industrial effluents were mixing. The fishes collected from the other two locations (locations A and C) were also noted to have significant incorporation of heavy metals within their tissues. The results indicate that the mixing of the wastewaters which are directly flushed into the river isdepleting the quality of the water as well as also affecting the flora and fauna of the river ecosystem. Accordingly, the incorporation of strict laws related to the discharge of various kinds of wastewater into the river should be focused on. Moreover, special attention should be emphasized to the various treatment strategies of the wastewaters prior to their discharge.

Conclusion

The water quality of the river is degrading rapidly due to various anthropogenic activities and industrial effluent discharges. Such discharges have a notable deleterious impact on the floral and faunal diversity of the river. In order to track the impact of the various point sources of pollution(in the form of discharge effluents),a comparative evaluation was carried out in this study. The three-point sources were selected in the form of location A (where domestic sewage is mixing with the river), location B (where industrial effluents were mixing), and location C (where various anthropogenic sources were taking place). The water samples were collected from the abovesaid locations, and thereby different characterizations were conducted. The obtained results indicated that most of the water quality parameters were beyond the permissible limit laid by the World Health Organization (WHO). The maximum deterioration of the river water was observed for location B where the industrial effluents were mixing. As the extended aim of the study, the fish samples were collected from various locations, and the bioaccumulation of the heavy metals into the gills and liver tissues was determined. The obtained results indicated that severe bioaccumulated heavy metals were observed. The highest levels of bioaccumulation of the heavy metals were observed within the fishes sampled from location B where the industrial effluents were mixing. The proposed scheme of the study will be definitely helpful for various stakeholders and will in turn help the various policy formations and renovation by various national and international agencies.

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